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—2— New U.S. Application
Docket No. 32860-000549/US

Description

Method and Apparatus For Balancing Capacitors in a Capacitor Bank

[0001] The present application hereby claims priority under 35 U.S.C. §119 on German patent application number DE 10236165.7 filed August 7, 2002, the entire contents of which are hereby incorporated herein by reference.

Field of the Invention

[0002] The invention generally relates to a method for balancing the capacitors in a capacitor bank, and to an apparatus for carrying out the method.

Background of the Invention

[0003] A capacitor bank is frequently used as an energy store, for example in a locomotive or in some other prime-mover rail vehicle, but in particular for stationary use in an overhead line. This capacitor bank ~~comprises~~ includes two or more parallel-connected rows of individual capacitors in each of the rows. T, and these capacitors may be what are referred to as ultracapacitors.

[0004] By way of example, the braking energy is temporarily stored in an energy store such as this in order to emit it again when the vehicle drives away. In order to allow as much energy as possible to be stored in a capacitor bank such as this, it is important for all the capacitors in a capacitor bank to be loaded uniformly, that is to say to be charged uniformly and completely. This process is called "balancing".

[0005] If a capacitor voltage which is greater than the nominal voltage is present on individual capacitors, even if only for a short time, then this leads to this capacitor ageing more quickly. In the worst case, it must then be removed prematurely, which is costly. Different voltages on the individual capacitors, which make the energy store inefficient, are essentially caused by capacitor characteristics, for example the equivalent series resistance and/or the resistance of the capacitor. Parallel resistances may also have an effect.

[0006] It is thus necessary to charge each individual capacitor in a capacitor bank to an upper voltage limit and to protect it against overcharging, which could lead to

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destruction of the capacitor. If the voltage that is applied is too high, this could lead to bubbles being formed in the electrolyte, which can burn and is toxic. However, it should be possible ~~by~~through the means-use of a diagnostic process, to identify in good time whether a capacitor is not fully serviceable.

[0007] It has already been proposed for voltage balancing to be carried out for all the capacitors (matching of the voltages which are present on the capacitors and the charges on the capacitors), in order that they are charged uniformly.

[0008] One known method provides for each capacitor to be charged individually. Small contactors are required to do this, which connect the capacitors to the power supply successively. This method takes a very long time. Furthermore, complex wiring is required.

[0009] It has already been proposed for the individual capacitors all to be balanced immediately on reaching a nominal value, with the aim of achieving uniform charging. A discharge path is required in parallel with each capacitor to do this. This method furthermore takes a very long time, if only a small balancing current is possible.

SUMMARY OF THE INVENTION

[0010] ~~The~~An embodiment of the invention is~~-may be~~ based on an~~the~~ object of specifying a method for uniform charging (balancing) of the capacitors in a capacitor bank. The method preferably,~~which~~ operates quickly and reliably and allows greater balancing currents without, however, requiring a large number of additional components. Such components,~~which would, if used,~~ occupy a large amount of space and ~~are~~would be highly susceptible to failure, in large capacitor banks with, for example, a thousand capacitors.

[0011] An embodiment of the invention also may be directed to an apparatus for carrying out the method~~will also be specified.~~

[0012] An~~The~~ object of specifying a method may be~~is~~ achieved, according to an embodiment of the invention, wherein~~in that~~ three voltage levels are produced by a reference voltage source in order to monitor the state of charge of the capacitors,

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~~in that~~ the capacitor voltage on each capacitor is determined and is compared with the voltage levels, and ~~in that~~ wherein a correct charge on a capacitor is indicated when the capacitor voltage is between the two lower voltage levels. Further, in that a fault in the capacitor may be indicated when the capacitor voltage is greater than the highest voltage level. Also, and in that balancing may be carried out only when neither a correct charge nor a fault is indicated.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] ~~All that is required~~ F for this method, ~~is~~ a simple electronic circuit may be used, in which the number of components required is minimal. The susceptibility to failure is thus likewise low. The balancing quality is ensured by the reference voltage source, since a constant source which is largely free of temperature influences is chosen.

[0014] This reference voltage source may produces three voltage levels, which are made available to evaluation electronics. The lowest level and the central level define a window in which all the capacitors must be after a fault-free charging process. The highest level defines a protection threshold.

[0015] Overshooting of this highest level ~~is~~ may be an indication of a fault. The fault may be indicated visually. It is also possible to use a bus system to inform an evaluation unit of the fault, thus allowing immediate diagnosis of which capacitor has failed. Suitable voltage values for the individual voltage levels are 2.2 V for the lowest voltage level, 2.45 V for the central voltage level and 2.7 V for the highest voltage level.

[0016] The method, according to an embodiment of the invention, advantageously ~~means indicates~~ that the balancing and, furthermore the monitoring of the capacitor bank can be carried out quickly and reliably using simple ~~means~~ devices.

[0017] By way of example, a fault in the capacitor is indicated when the gradient of the voltage on the capacitor during the charging of the capacitor exceeds a limit value. This advantageously provides additional capability for identifying a defective capacitor.

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[0018] The voltage levels ~~are~~ may be supplied, for example via optocouplers, to an evaluation device. This transmission method is particularly reliable.

[0019] By way of example, the setting up of the reference voltage source makes use of a voltage which is present in the capacitor bank. Advantageously, no additional voltage supply is thus required.

[0020] By way of example, the sum voltage across two capacitors in the capacitor bank is tapped off as a voltage source for balancing. The two capacitors are in this case two adjacent capacitors, and this can be done particularly easily.

[0021] A converter ~~is~~ may be inserted upstream of the first capacitor in the capacitor bank, instead of the faulty capacitor, in this case, ~~so that~~. As such, the voltage which is otherwise present on two capacitors, is produced.

[0022] ~~The said~~ voltage source for balancing can achieves the advantage that an increased balancing voltage is available using simple ~~means~~ devices. Further, ~~and~~ for the first time, it may allows rapid balancing, when required.

[0023] After charging the capacitors, normal operation is started for one capacitor, for example, when the capacitor voltage reaches the lowest voltage level and has not yet reached the central voltage level. A balancing operation may starts when the capacitor voltage has reached the central voltage level, and may ends when the capacitor voltage has once again reached the lowest voltage level. When the lowest voltage level is reached once again, normal operation is started again. A fault is indicated on reaching the highest voltage level. This can be initiated by a defective capacitor. These individual method steps ensure optimum balancing and fault indication.

[0024] In order to start balancing operation, the capacitor voltages of all the capacitors are raised above the central voltage level.

[0025] ~~A The object of specifying an apparatus for carrying out the method is achieved,~~ according to an embodiment of the invention, ~~in that may include a~~ series circuit formed from a non-reactive resistor and a first transistor, ~~is arranged in parallel with in each case two or more capacitors in the capacitor bank.~~ Ak, in

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~~that~~ at least one further transistor ~~is~~ may be connected in parallel with the first transistor. Further, in that the transistors my be connected to an evaluation device, ~~and in that~~ with voltage taps on the capacitors being ~~are~~ connected to the evaluation device.

[0026] The capacitor bank may include ~~comprises~~, for example, four to eight capacitors, in particular six capacitors.

[0027] The desired voltage levels can thus be produced from the voltage of the capacitors that are to be balanced and/or to be monitored.

[0028] Even as few as ~~Only one~~ voltage tap ~~is required~~ may be used for parallel-connected capacitors, since capacitors which are connected in parallel automatically balance one another. The number of components required ~~is~~ may thus be reduced further.

[0029] Optocouplers, which are connected to the evaluation device, ~~are~~ may be connected to the capacitors and can be used to transmit the voltage levels to a bus system. This can be achieved, for example, owing to the DC isolation which is required for this purpose.

[0030] A double coupler may also be used instead of three optocouplers.

[0031] The non-reactive resistor in the series circuit that is ~~required~~ used for balancing is used as a discharge resistor and may, for example, be a large wire resistor. It may also be a flat-bottom resistor, an HSA resistor or else a cement resistor. The transistors are generally what are referred to as field-effect transistors. If necessary, these field-effect transistors may be equipped with heat sinks. The voltage of the reference voltage source is used as a gate driver voltage for the field-effect transistors. The desired voltage levels are produced as a function of the number of parallel-connected transistors and, possibly, on the basis of the configuration of the transistors.

[0032] In order to indicate a fault, the evaluation device may advantageously be connected to a light-emitting diode.

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[0033] The method, according to an embodiment of the invention, and ~~the~~ an apparatus for carrying out the method, ~~in particular~~ may achieve the ~~an~~ advantage that suitable voltage levels are provided using simple ~~means~~ devices which then advantageously allow reliable statements to be made about the uniform charging of the capacitor bank, and about any possible defects in a capacitor, by comparison with the instantaneous voltage of one capacitor in a capacitor bank.

[0034] Advantageously, balancing may be carried out only when it is no longer possible to keep the capacitor voltages of all the capacitors between the two lower voltage levels.

[0035] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.